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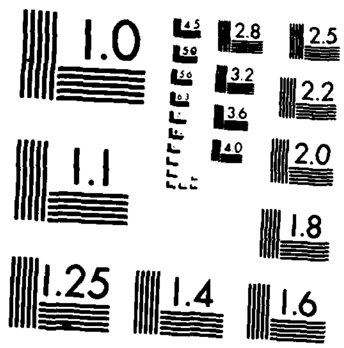

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ESTABLISHMENT OF PROCEDURAL METHODOLOGY AND DATA INTERPRETATION FOR FUEL QUALITY EVALUATION

INTERIM REPORT
BFLRF No. 212

By

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Under Contract to

U.S. Army Belvoir Research, Development and Engineering Center
Materials, Fuels and Lubricants Laboratory
Fort Belvoir, Virginia

Contract No. DAAK70-85-C-0007

March 1986

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SECURITY CLASSIFICATION OF THIS PAGE

ADA173872

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS None
2a. SECURITY CLASSIFICATION AUTHORITY N/A 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Interim Report BFLRF No. 212	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Belvoir Fuels and Lubricants Research Facility (SwRI) 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Southwest Research Institute 6220 Culebra Road San Antonio, TX 78284	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Belvoir Research, Development & Engineering Center 8b. OFFICE SYMBOL (If applicable) STRBE-VF	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DAAK70-82-C-0001; WD 1 DAAK70-85-C-0007; WD 13
8c. ADDRESS (City, State, and ZIP Code) Ft. Belvoir, VA 22060-5606	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO.: 63104 PROJECT NO.: 1L263104D150 TASK NO.: 7c WORK UNIT ACCESSION NO.:

11. TITLE (Include Security Classification)
Establishment of Procedural Methodology and Data Interpretation for Fuel Quality Evaluation (U)

12. PERSONAL AUTHOR(S)
Westbrook, S.R.; Stavinoha, L.L.; Owens, E.C.; Bundy L.L.; and Butler, Jr., W.E.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Interim	FROM Oct 83 TO Sept 85	1986 March	27

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Diesel Fuel; Fuel Analysis; Fuel Monitoring
			Jet Fuel; Field Test
			JP-4; Fuel Quality Evaluation

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report summarizes the results of a program to monitor fuel quality and fuel usage parameters at four test sites. The program was intended to provide baseline data for a demonstration that shale-derived fuels are acceptable for use in aircraft and in ground vehicles and equipment. Fuel samples (diesel or JP-4) were obtained and analyzed for specification conformance. Fuel usage was monitored as was the usage of fuel wetted components at each test site. Other data obtained included results of the Army Oil Analysis Program (AOAP) and vehicle operational data. Methods of sampling, sample analysis, data analysis, and reporting are discussed. An overview of the results is also presented.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Mr. F.W. Schaekel	22b. TELEPHONE (Include Area Code) (703) 664-3576 22c. OFFICE SYMBOL STRBE-VF

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

FOREWORD

This work was conducted at the Belvoir Fuels and Lubricants Research Facility (SwRI) located at Southwest Research Institute (SwRI), San Antonio, TX under Contract Nos. DAAK70-82-C-0001 and DAAK70-85-C-0007 during the period October 1983 through September 1985. The work was funded by the U.S. Army Belvoir Research, Development and Engineering Center, Ft. Belvoir, VA, with Mr. F.W. Schaekel (STRBE-VF) as the Contracting Officer's representative and Mr. M.E. LePera, Chief of Fuels and Lubricants Division (STRBE-VF), as the project technical monitor.

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ACKNOWLEDGMENT

The helpful assistance of Dr. J.V. Mengenhauser, U.S. Army Belvoir Research, Development and Engineering Center, STRBE-VF, throughout this program is acknowledged.

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I. INTRODUCTION AND BACKGROUND

In 1983 the U.S. Army began a field validation test in joint participation with the U.S. Air Force in the Department of Defense's (DOD) project "Rivet Shale." The program was intended to demonstrate that shale-derived fuels are acceptable for use in aircraft and in ground vehicles and equipment.

The approach was to monitor the fuel and fuel usage parameters at each test site for a prescribed period prior to delivery of shale-derived fuel. These data will be used to establish a comprehensive data base against which equivalent data obtained after the delivery of shale fuel could be compared.

Test sites were selected to be in geographic proximity to the shale fuel refiner (Grand Junction, CO) in order to minimize the impact on transportation and delivery costs. The sites selected for testing shale diesel fuel were Fort Carson, CO and Dugway Proving Ground, UT. After AVSCOM approval of shale-derived JP-4 testing in October 1984, two additional test sites were added: Michael Army Airfield located in Dugway Proving Ground and the Army National Guard activity located at Salt Lake City Airport No. 2, West Jordan, UT.

II. FIELD MONITORING OBJECTIVES

To demonstrate the acceptability of shale-derived fuels in U.S. Army vehicles and equipment currently authorized for operation on conventionally refined diesel fuel meeting VV-F-800C specifications and JP-4 fuel meeting MIL-T-5624L specifications, the following objectives were established for this program:

- Compare the equivalent performance of shale-derived fuel with that of petroleum-derived fuel in operational equipment.
- Determine the impact of shale fuel on user equipment and operations.
- Quantify any operational problems and benefits resulting from the use of shale-derived fuels.
- Conduct laboratory tests and analyses to determine the quality of shale-derived fuel.

III. FIELD MONITORING ACTIVITIES

In order to accomplish the goals outlined for this program, the following activities were identified:

- Routine sampling of fuel storage facilities at each test site and laboratory analysis of each fuel sample; concurrent measurement of each tank for fuel and water bottom levels.
- Compilation of data on fuel-wetted component usage, oil analysis program (AOAP) results, replacement of major vehicle assemblies, and fuel consumption.

Diesel fuel samples were obtained from each major fuel storage tank (not vehicle storage) at both test sites. Samples of JP-4 were taken from Michael Army Airfield at Dugway Proving Ground and the Army National Guard, West Jordan, UT. All fuel samples were airshipped to Belvoir Fuels and Lubricants Research Facility (SwRI) (BFLRF) where laboratory analyses were performed.

During the 2-year *shale fuel validation* program, fourteen field trips were made to Fort Carson and thirteen field trips to Dugway Proving Ground to collect fuel samples. On the last twelve trips made to Dugway Proving Ground, the sampling team took JP-4 samples from Michael Army Airfield at Dugway. Finally, in October of 1984 the Army National Guard at West Jordan, UT became involved in the program, and a total of six field trips were made to collect JP-4 samples at that site.

In order to establish a petroleum fuel data base from which data could be extracted and compared with shale fuel data, the following areas were identified as legitimate and viable areas of interest in addition to the obvious chemical tests and analyses which would be performed on the baseline and test fuels:

- Fuel-wetted component usage for vehicles and equipment included in the test at each test site.

- Results of laboratory tests and analyses performed by Army Oil Analysis Program (AOAP) laboratories on used oil samples provided by the using units.
- Replacement figures for major vehicle and equipment assemblies such as engines and, where applicable, transmissions.
- Operational data, to include miles or hours of operation, gallons of fuel consumed and quarts of oil consumed.

It was directed that the data be acquired at the highest possible level to minimize the impact on the duties and responsibilities of maintenance and operational personnel. Points of contact (POCs) were appointed at post/activity level to assist field monitors in acquiring the data available at each test site.

Because of special circumstances at each test site such as number of personnel, quantities and types of equipment, mission/training requirements, and sophistication of automated data processing programs, it was determined that not all the data could be feasibly acquired at each test site. At Fort Carson, the data were obtained as follows:

- Fuel-wetted component usage - Director of Logistics (DOL) level. National stock numbers (NSNs) for components, assemblies and parts were provided the Chief, Plans and Policies Division of DOL who caused the information to be included in a computer software program which would provide quarterly printouts of the desired information.
- AOAP data were obtained on magnetic computer tapes from the historical data center at Kelly Air Force Base, San Antonio, TX, after approval to obtain the tapes was received from the Materiel Readiness Support Activity (MRSA), Lexington, KY.
- Reliable replacement figures for vehicle and equipment assemblies have been difficult to obtain at any level. It is believed that the information can finally be obtained from the Logistics Management Division in DOL.
- Operational data were obtained from two sources - (1) The Training Management and Control System (TMACS) section in the 4th Division

Headquarters provided data for all divisional units, (2) The Petroleum, Oil and Lubricants (POL) section of DOL provided data for nondivisional units.

At Dugway Proving Ground, UT, the only significant data that could be obtained were the diesel fuel usage for ground equipment and JP-4 fuel usage for Michael Army Airfield. JP-4 fuel usage at the Army National Guard Activity at West Jordan, UT was the only significant data available.

It should be noted here that circumstances and conditions are in a constant state of flux at any military installation, such as:

- Personnel changes at all levels.
- Automated Data Processing equipment breakdowns.
- The type and mix of vehicles and equipment.
- Authorized fuel consumption rates.
- Mission/training activities.
- Physical relocation of sections responsible for providing important data.

Finally, a field validation test of this size and complexity must have the constant attention and supervision of field monitors external to the military units participating in order to ensure the proper direction of the program at the post/activity concerned and to ensure that samples, if taken, and required data are of the quantity and quality desired.

IV. SAMPLING TECHNIQUE

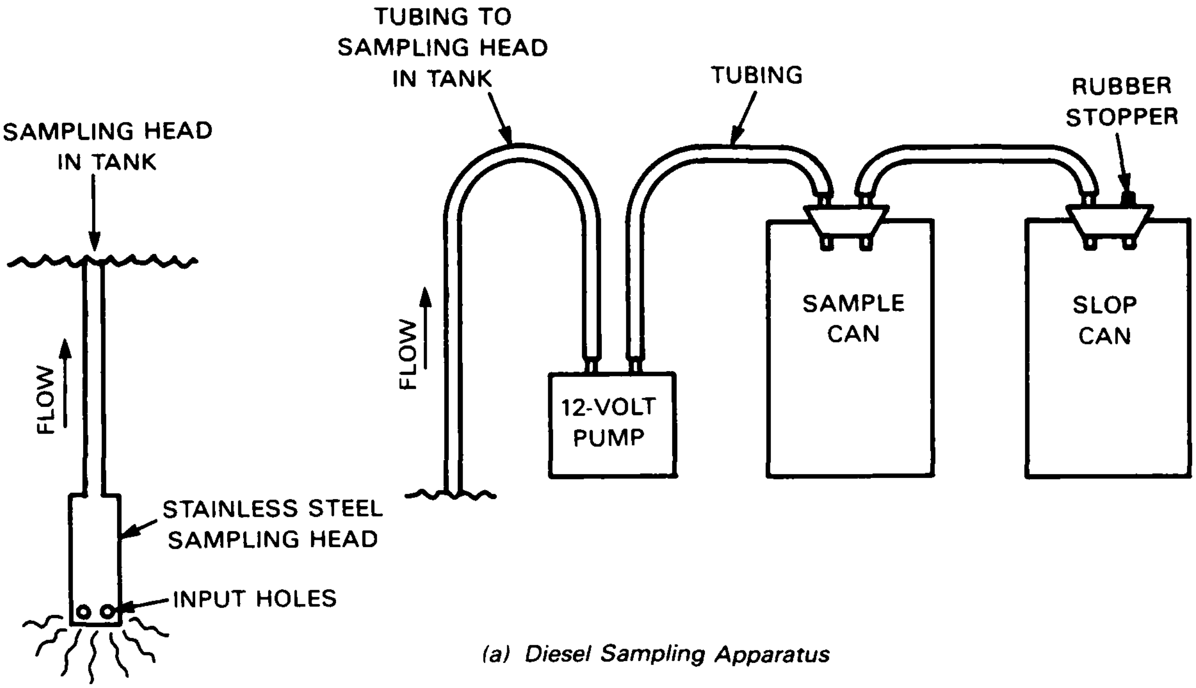
The initial approach for obtaining fuel samples was to take nozzle samples from storage tanks with a dispensing pump and use a fuel sampling bomb (Bacon Bomb) to obtain samples from the middle of tanks without a dispensing pump. This approach proved to be inadequate for two reasons. Even after dispensing 5 gallons from the dispensing hose, the fuel sample was found to be nonrepresentative in several cases. The fuel sampling bomb was time consuming, and variations in fill/vent pipe diameters necessitated carrying at least two samplers. To relieve these inadequacies, a new sampling system was devised.

The new sampling system utilized two small battery-powered (12 volts DC) pumps, plastic tubing, slop fuel containers, and sample cans. A block diagram of the apparatus is shown in Figure 1a. This apparatus was used to obtain diesel fuel samples. A slight modification (Figure 1b) of this apparatus was used for obtaining JP-4 samples. In the modified apparatus, a hand vacuum pump was used for safety reasons. The pump was attached to the slop can (which served as a vacuum reservoir), the vacuum reservoir was attached to the sample can, and the sampling hose was attached to the sample can. In each apparatus, rubber stoppers with holes in them were used in the can openings to prevent dirt and debris from entering the can.

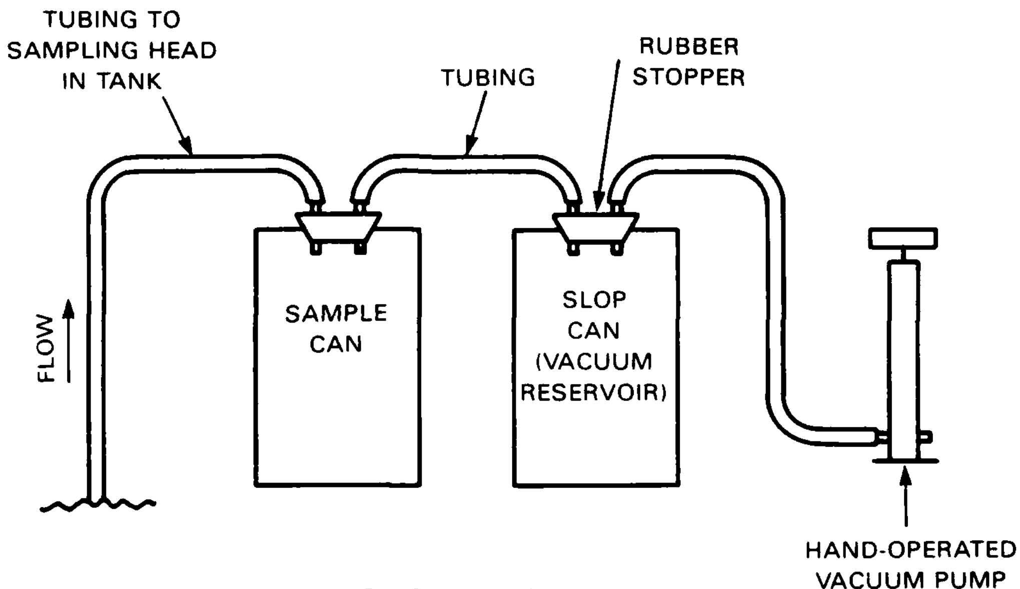
Diesel fuel samples were taken from two levels in the tank--middle of the fuel level and bottom of the tank. Separate sampling apparatus were used for middle and bottom samples. The depth of the water bottom in each tank was also measured. For the bottom sample, the probe was constantly raised and lowered through the bottom 12 inches of the tank. This pulsing action produced a sample which was more representative of the condition of the bottom of the tank. Diesel fuel samples were drawn into clean 1-gallon cans.

Samples of JP-4 were taken from the middle of the fuel level. Samples of JP-4 were taken in clean 1-gallon epoxy-lined cans. Each sample can was also rinsed with sample fuel before the actual fuel sample was taken.

Each storage tank at each test site was assigned a unique identification number to simplify sampling, data storage, and reporting.



(a) Diesel Sampling Apparatus



(b) JP-4 Sampling Apparatus

FIGURE 1. BLOCK DIAGRAM OF FUEL SAMPLING APPARATUS

V. FUEL ANALYSES PERFORMED

During this 2-year interval, laboratory tests and analyses were performed on 907 samples of diesel fuel and 183 samples of JP-4 fuel.

A. Diesel Fuel Samples

The bottom samples were used to give an indication of the condition in the bottom 12 inches of the fuel tank. The bottom samples were shaken, allowed to stand for 24 hours, and then a sample of the fuel was withdrawn for analyses as follows:

- Visual Appearance, D 4176
- Water and Sediment, D 2709
- Color, D 1500
- Gravity, °API, D 1298
- Density, D 1298

The middle samples were considered more representative of the overall fuel in the tank and were given more extensive laboratory analyses as follows:

- Visual Appearance, D 4176
- Water and Sediment, D 2709
- Accelerated Stability, D 2274
- Cloud Point, D 2500
- Distillation, D 86
- Cetane Number, D 613
- Carbon Residue, D 524
- Cetane Improver, VV-F-800C Appendix
- Color, D 1500
- Particulate Contamination, D 2276
- Sulfur Content, X-Ray Fluorescence
- Flash Point, D 93
- Gravity, °API, D 1298
- Density, D 1298
- Cetane Index, D 976
- Bureau of Mines Origin Test

The majority of the laboratory tests and analyses performed on the diesel fuel samples were chosen from the VV-F-800C specification requirements. This was done to establish a data base of specification values with which to compare the shale-derived fuels.

The test for color, ASTM D 1500, was chosen as an additional monitoring tool. A significant change in the color could be an indication of a change in the stability characteristics of the fuel.

The Bureau of Mines Origin Test was included to screen the fuels in order to determine what types of stocks they are composed of as an input to possible future additive treatment considerations.

An additional particulate contamination test, based on a modified ASTM D 2276, was also included. The test was modified to use 500-milliliter portions of the sample, filtered through 1.5-μm size glass fiber filters. These glass fiber filters could then be washed with triple solvent (a mixture of equal portions of toluene, acetone, and methanol) to give an indication of the types of debris present in the sample. This triple solvent will dissolve fuel degradation products but will not dissolve inorganic debris (dust, dirt, metals, etc.) or microbiological debris. An elemental analysis could then be performed on the debris on the washed filters to measure metals content.

The water and sediment test, ASTM D 2709, was used to quantify the sediment or dissolved water that may be present in a fuel. This is a useful indicator of the cleanliness of a fuel.

B. JP-4 Fuel Samples

Four gallons of JP-4 were taken from each storage tank to allow enough fuel for the following laboratory tests and analyses:

- Color, D 156
- Visual Appearance, D 4176

- Total Acid Number, D 3242
- Aromatics, D 1319
- Olefins, D 1319
- Sulfur Content, X-Ray Fluorescence
- Distillation, D 86
- Hydrogen, D 3178
- Net Heat of Combustion, D 240
- Existent Gum, D 381
- Total Solids, Appendix A, MIL-T-5624L
- Filtration Time, Appendix A, MIL-T-5624L
- Fuel Electrical Conductivity, D 3114
- Fuel Icing Inhibitor
- Thermal Oxidation Stability Test (JFTOT), D 3241
- Ball-on-Cylinder Lubricity Evaluation (BOCLE)
- Corrosion Inhibitor by Infrared
- Water Separation Characteristics, Microseparometer, D 3948

The majority of the laboratory tests and analyses performed on the JP-4 fuel samples were chosen from the MIL-T-5624L specification. The shale-derived JP-4 must conform to the military specification. Therefore, a data base was established with which to compare the performance of the shale-derived fuel with petroleum-derived fuel.

The Ball-on-Cylinder Lubricity Evaluation (BOCLE) test was added to the program as a measure of fuel lubricity.

The test for water separation characteristics, ASTM D 3948, was added to detect the presence of harmful levels of surfactants in JP-4.

Due to the time lapse between the expected delivery date (2QFY84) of shale-derived fuels and the to be determined actual delivery at some future date, an exhaustive number of tests and analyses have been performed on a substantial volume of petroleum-derived diesel fuel and JP-4 fuel. Consequently, there now exists a comprehensive data base with which to compare the shale-derived fuels after the arrival of the shale fuels at the three test sites.

VI. SUMMARY OF FUEL CONDITION AT FORT CARSON

Based on the results of laboratory tests and analyses, the general condition of the fuel at Fort Carson appears to be quite good. Test results indicate that the fuel is clean and stable overall.

The potential for microbiological growth has been indicated at Fort Carson since evidence of growth has been detected in several vehicle fuel tanks. There has been no firm evidence, however, of significant growth in the storage tanks.

Water bottoms have been found in several of the storage tanks; but this problem is common in underground tanks and appears to have caused no problems to date.

A few of the samples were contaminated with a low flash point material, most probably gasoline. Appropriate personnel at Fort Carson were alerted to this contamination as soon as it was discovered, and proper corrective measures were taken.

Fort Carson personnel have been very conscientious in maintaining the fuel storage tanks and in the use of proper procedures for fuel handling.

Fort Carson fuel characteristics for the cumulative volume for fiscal years 1984 and 1985 are compared to the specification limits of specific tests in Figures 2 through 6. The tests selected for comparison are:

- Figure 2. Sulfur, X-Ray Fluorescence, mass%
- Figure 3. Accelerated Stability, D 2274, mg/100 mL
- Figure 4. Cetane Number, D 613
- Figure 5. Particulate Contamination, D 2276, mg/L
- Figure 6. Cloud Point, D 2500, °C

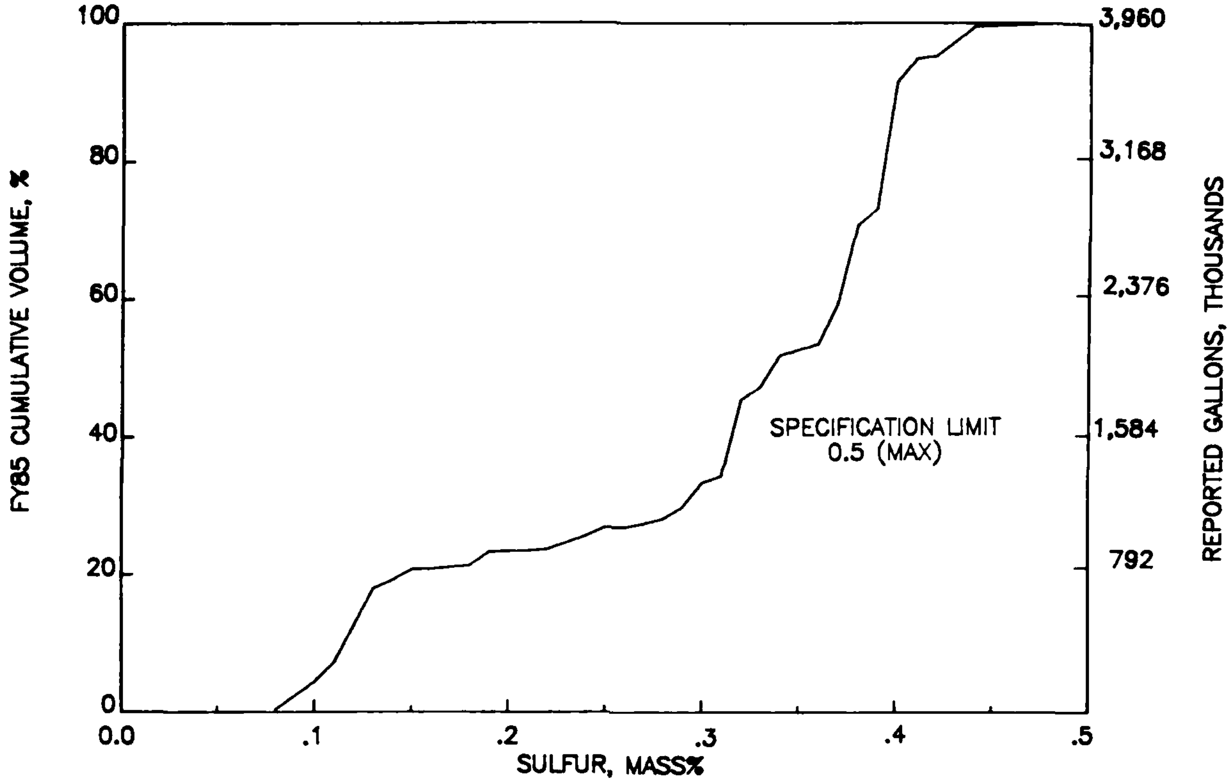


FIGURE 2. SULFUR, X-RAY FLUORESCENCE, MASS% (FORT CARSON, CO)

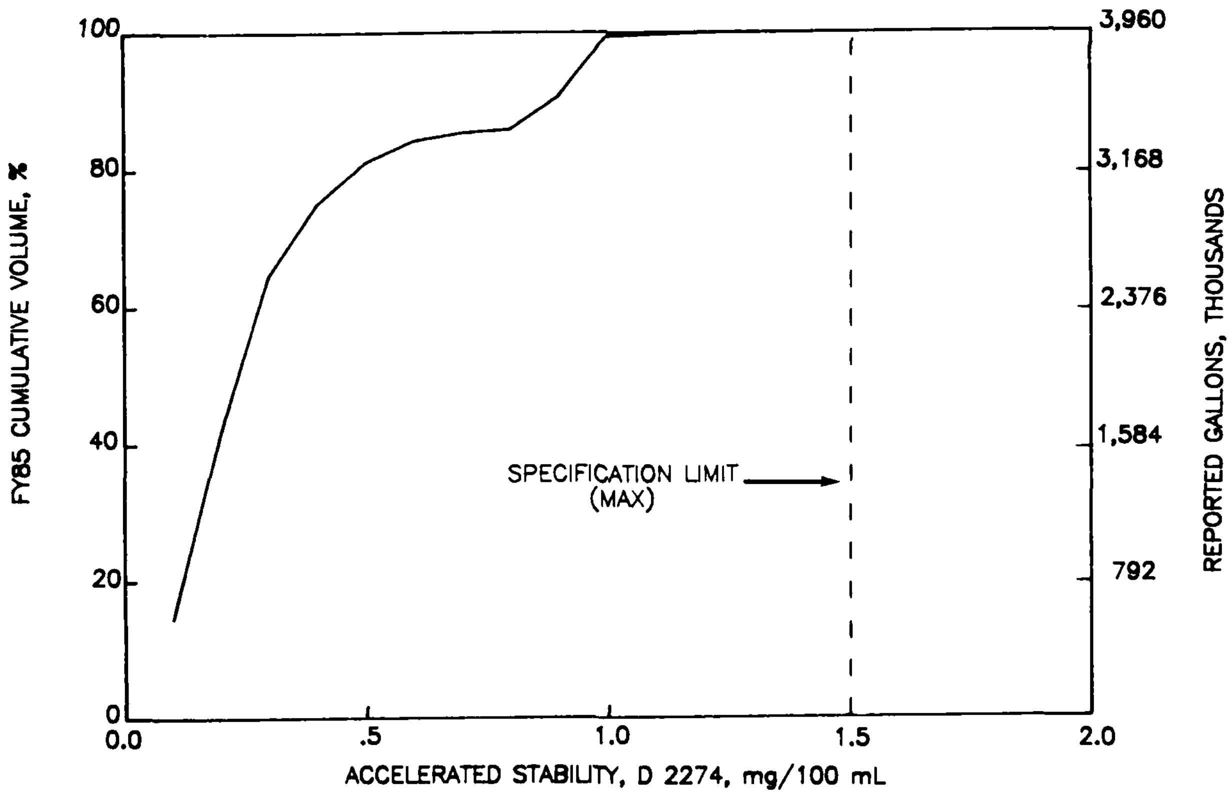


FIGURE 3. ACCELERATED STABILITY, D 2274, mg/100 mL (FORT CARSON, CO)

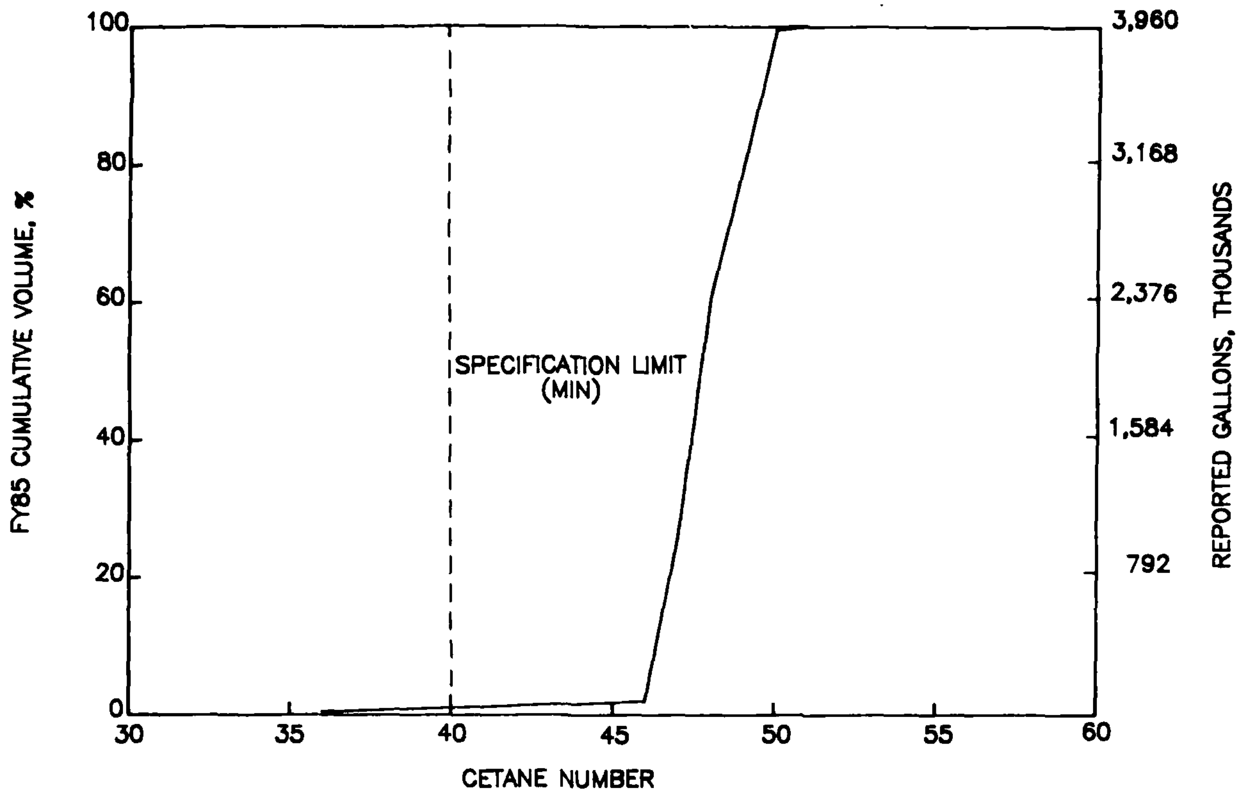


FIGURE 4. CETANE NUMBER, D 613 (FORT CARSON, CO)

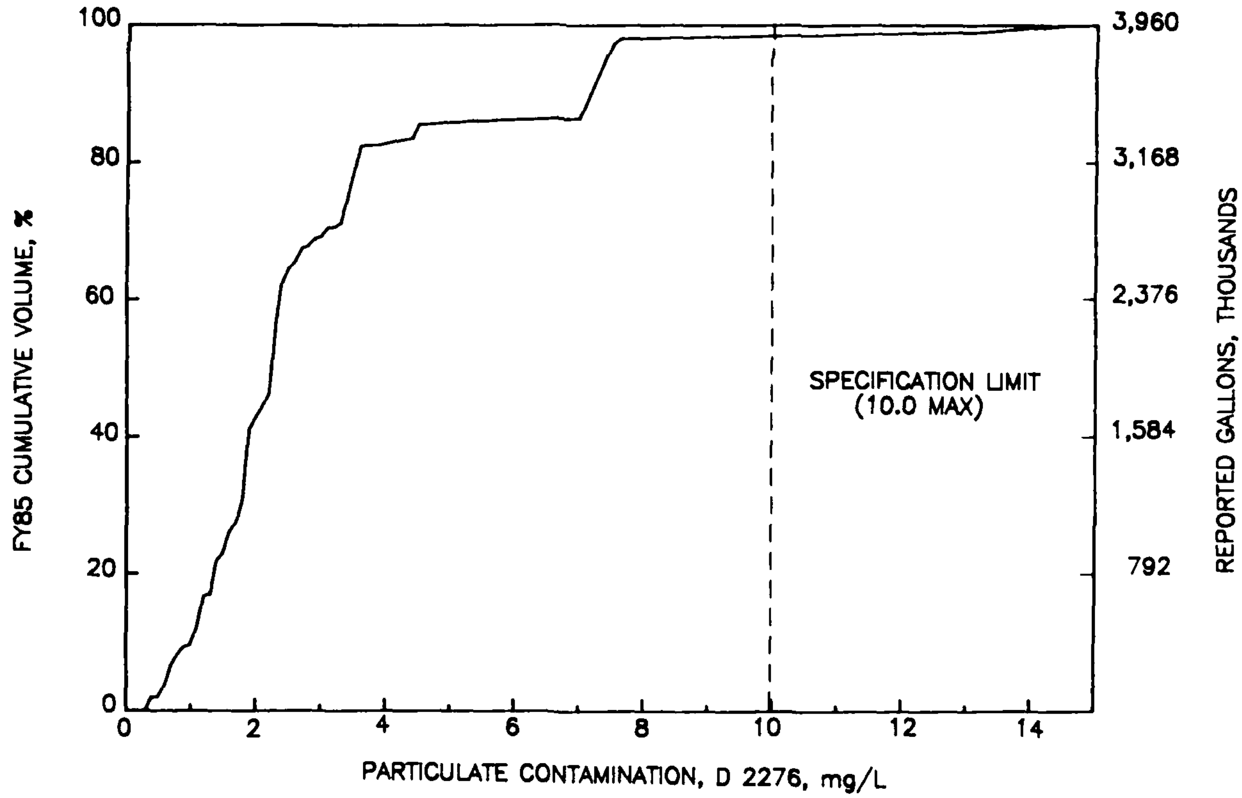


FIGURE 5. PARTICULATE CONTAMINATION, D 2276, mg/L (FORT CARSON, CO)

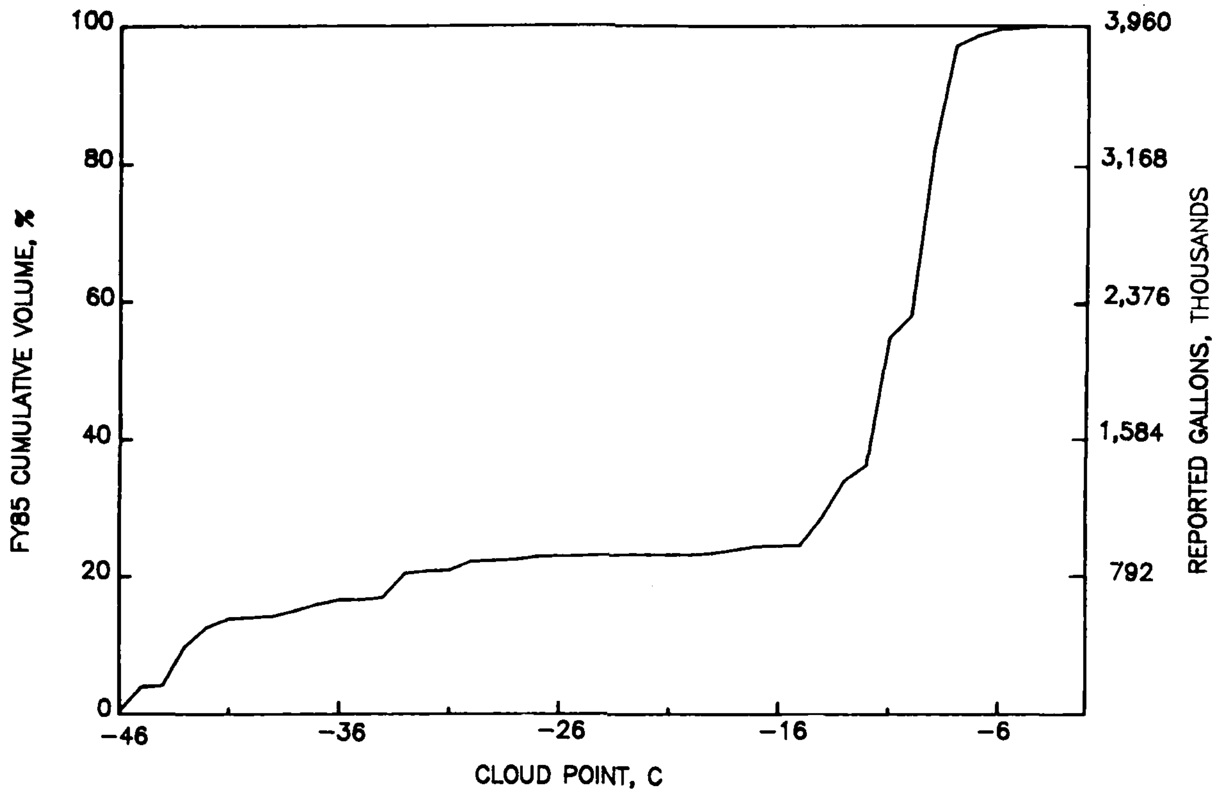


FIGURE 6. CLOUD POINT, D 2500, °C (FORT CARSON, CO)

The cumulative volume of the fuel for the 2 years is well within the VV-F-800C specification limits with only one exception. The particulate contamination, ASTM D 2276, as shown in Figure 5, indicates less than 3 percent of the cumulative volume over a 2-year period is not within the 10.0 mg/L maximum specification limits. This indicates a clean and stable fuel overall.

Figures 7 through 11 present the high, average, and low test results for each of the sampling periods as follows:

- Figure 7. Sulfur, X-Ray Fluorescence, mass%
- Figure 8. Accelerated Stability, D 2274, mg/100 mL
- Figure 9. Cetane Number, D 613
- Figure 10. Particulate Contamination, D 2276, mg/L
- Figure 11. Cloud Point, D 2500, °C

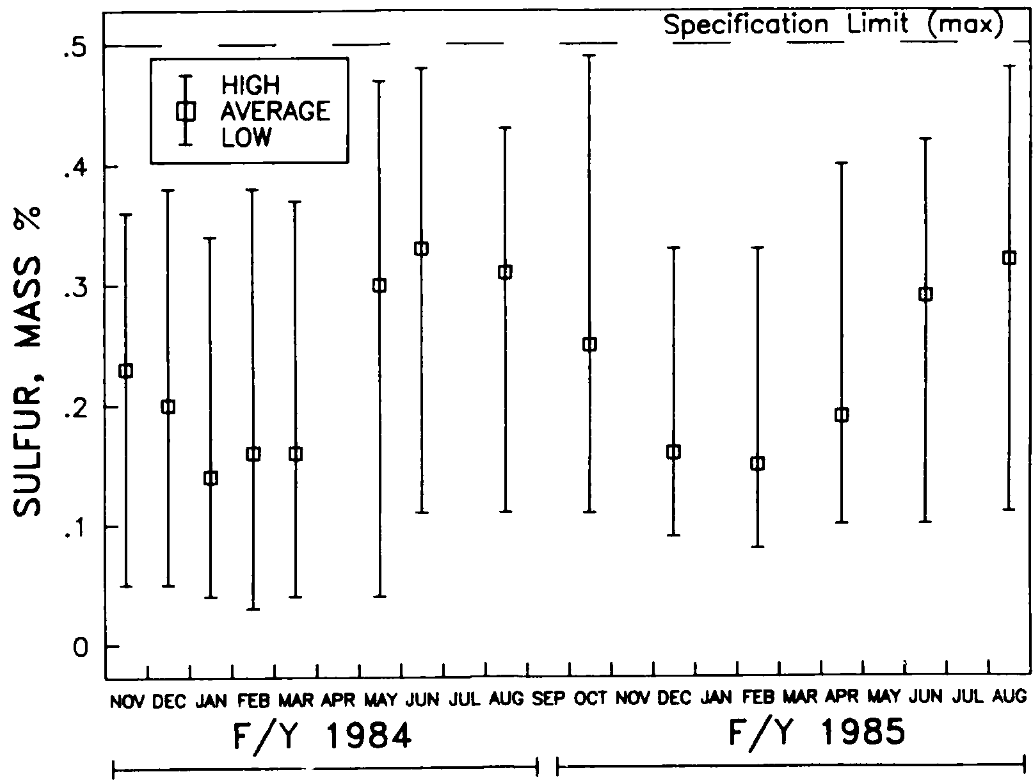


FIGURE 7. HIGH, AVERAGE, AND LOW VALUES FOR SULFUR, X-RAY FLUORESCENCE, MASS% (FORT CARSON, CO)

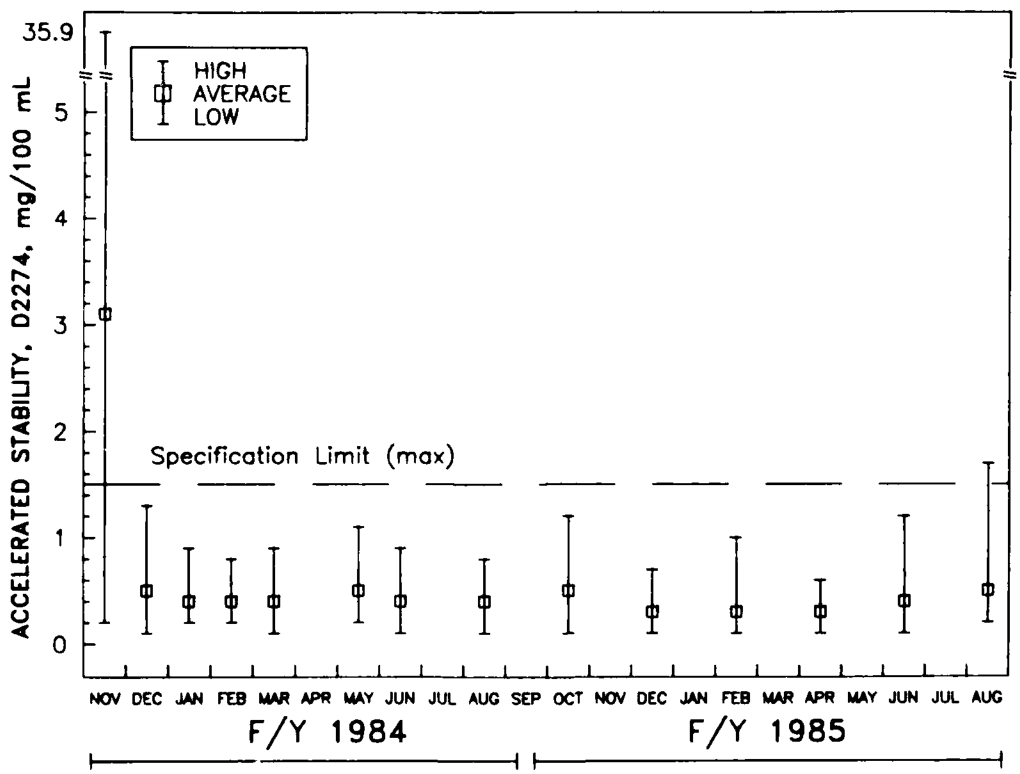


FIGURE 8. HIGH, AVERAGE, AND LOW VALUES FOR ACCELERATED STABILITY, D 2274, mg/100 mL (FORT CARSON, CO)

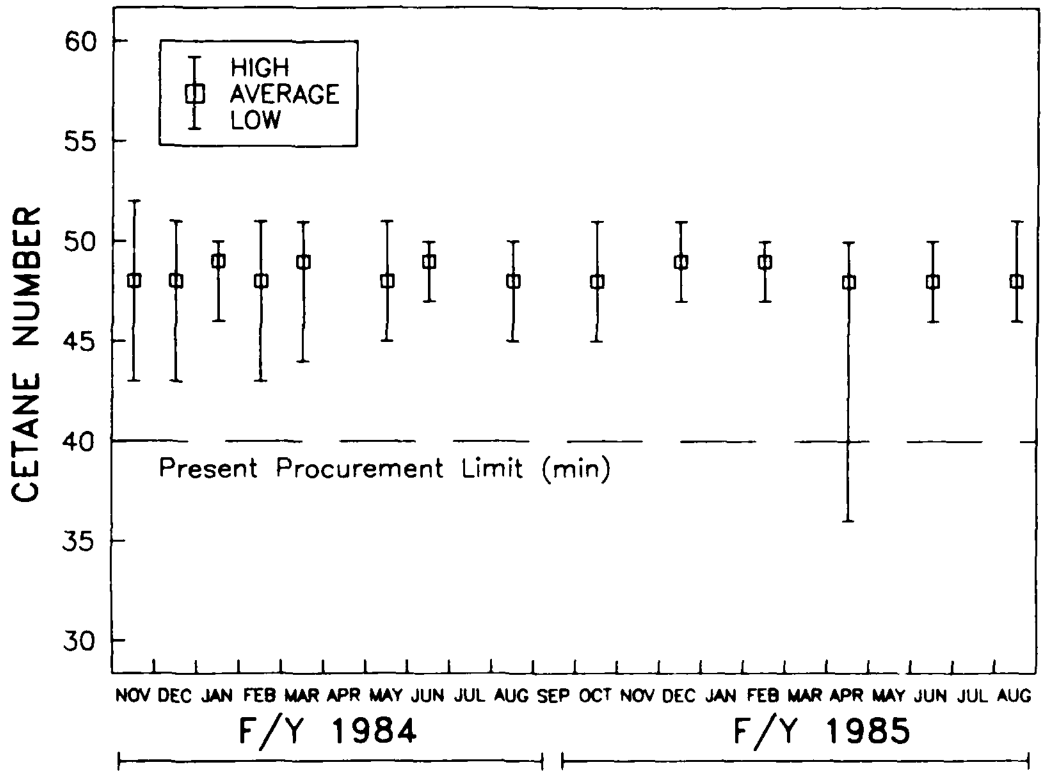


FIGURE 9. HIGH, AVERAGE, AND LOW VALUES FOR CETANE NUMBER, D 613 (FORT CARSON, CO)

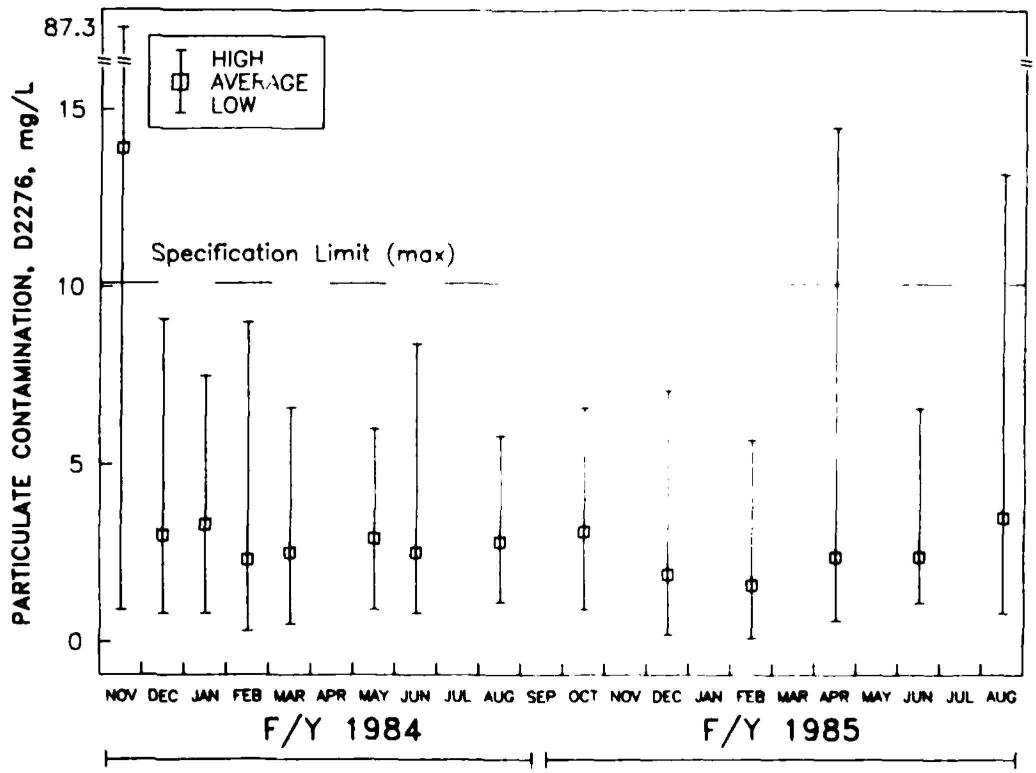


FIGURE 10. HIGH, AVERAGE, AND LOW VALUES FOR PARTICULATE CONTAMINATION, D 2276, mg/L (FORT CARSON, CO)

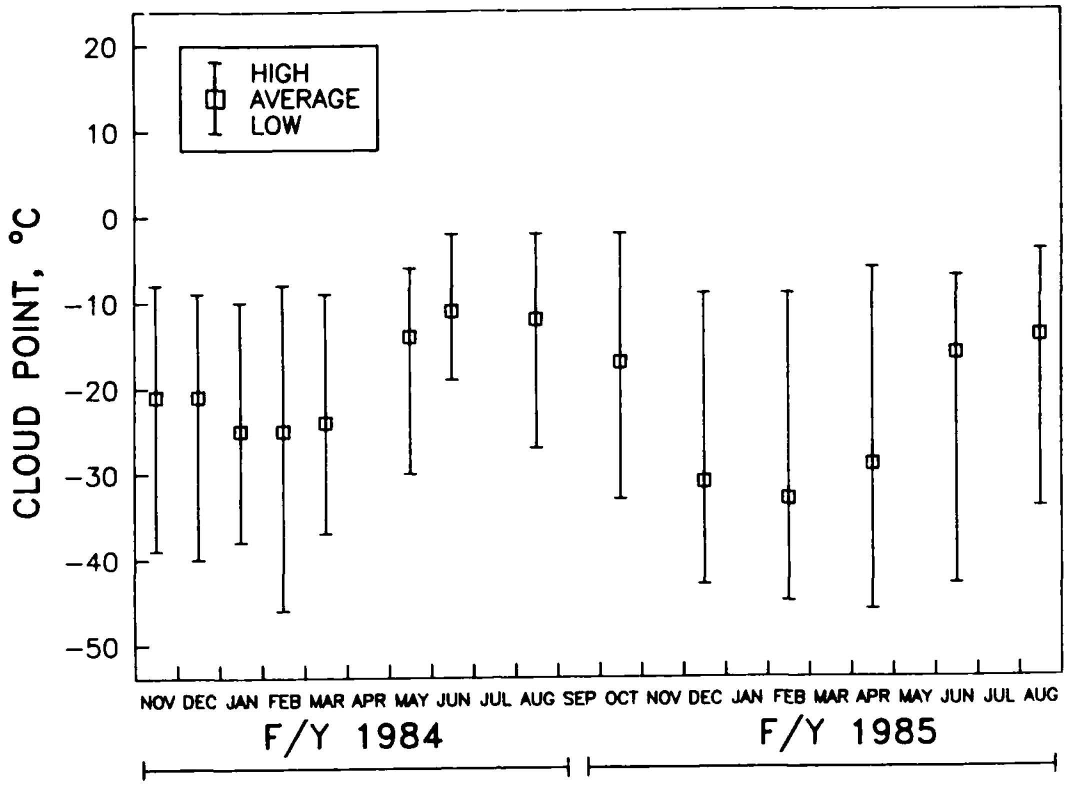


FIGURE 11. HIGH, AVERAGE, AND LOW VALUES FOR CLOUD POINT, D 2500, °C (FORT CARSON, CO)

VII. SUMMARY OF FUEL CONDITION AT DUGWAY PROVING GROUND

Based on the results of laboratory tests and analyses, the fuel appears to be in good condition in general. Test results indicate the fuel is clean and stable.

Figures 12 through 16 present the high, average, and low test results, from each sampling period, for the fuel at Dugway Proving Ground, as follows:

- Figure 12. Sulfur, X-Ray Fluorescence, mass%
- Figure 13. Accelerated Stability, D 2274, mg/100 mL
- Figure 14. Cetane Number, D 613
- Figure 15. Particulate Contamination, D 2276, mg/L
- Figure 16. Cloud Point, D 2500, °C

The potential for microbiological growth has been indicated in the diesel fuel storage tanks, but there has been no firm evidence of significant growth in the tanks.

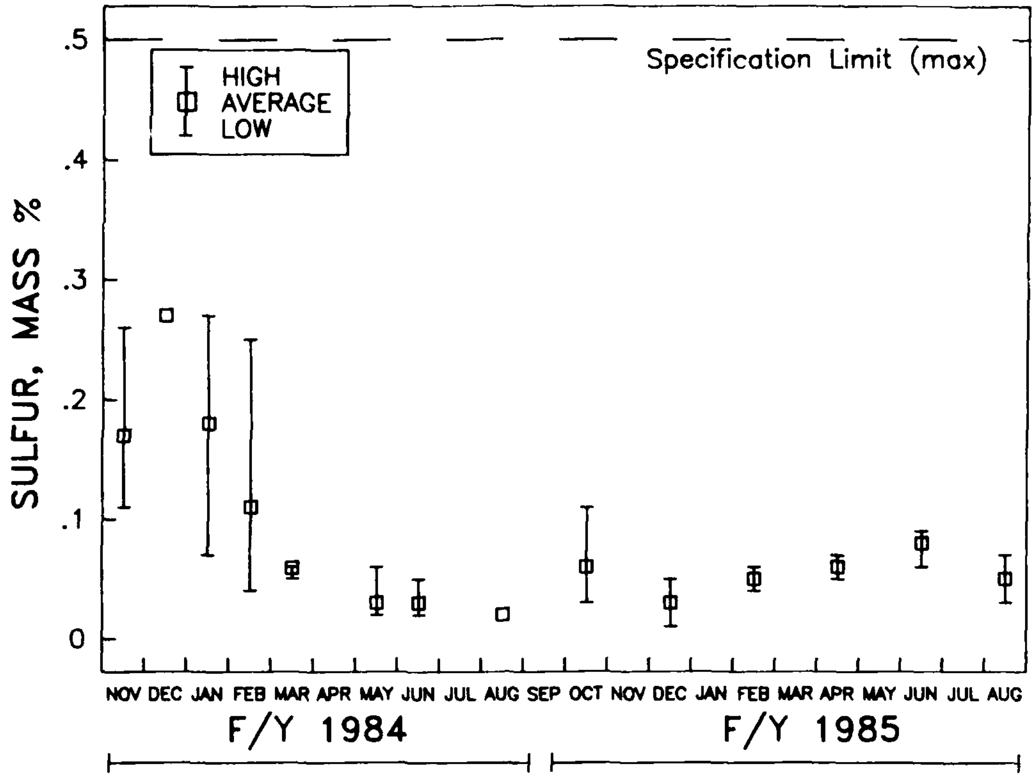


FIGURE 12. HIGH, AVERAGE, AND LOW VALUES FOR SULFUR, X-RAY FLUORESCENCE, MASS% (DUGWAY PG)

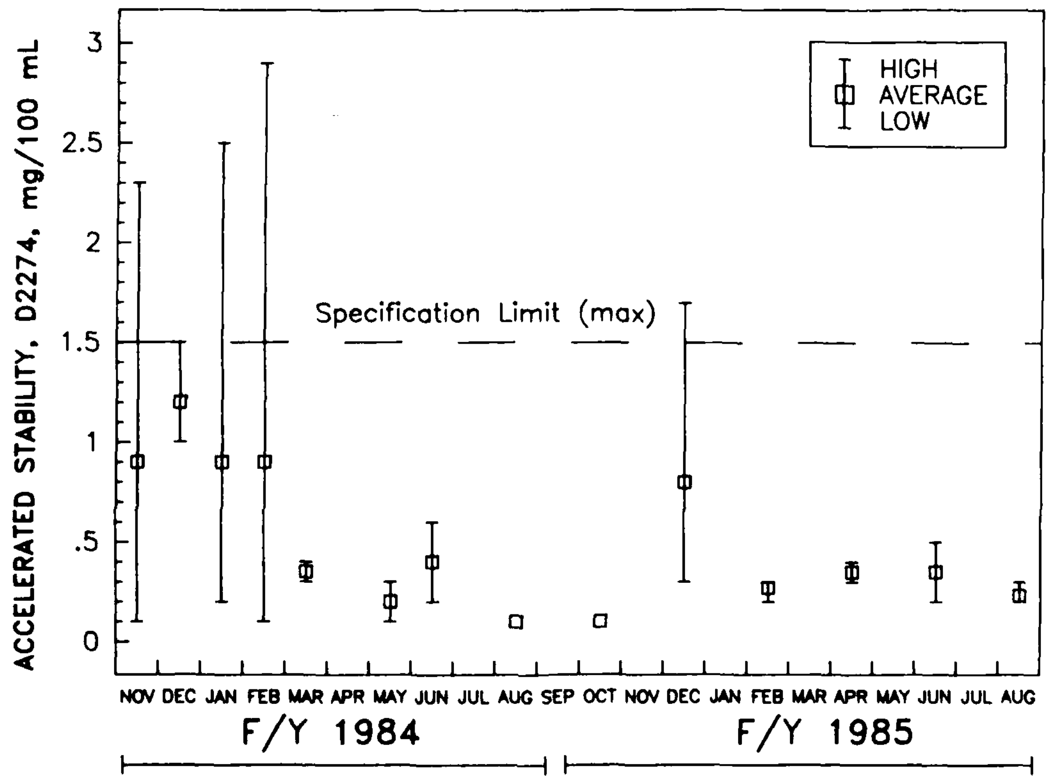


FIGURE 13. HIGH, AVERAGE, AND LOW VALUES FOR ACCELERATED STABILITY, D 2274, mg/100 mL (DUGWAY PG)

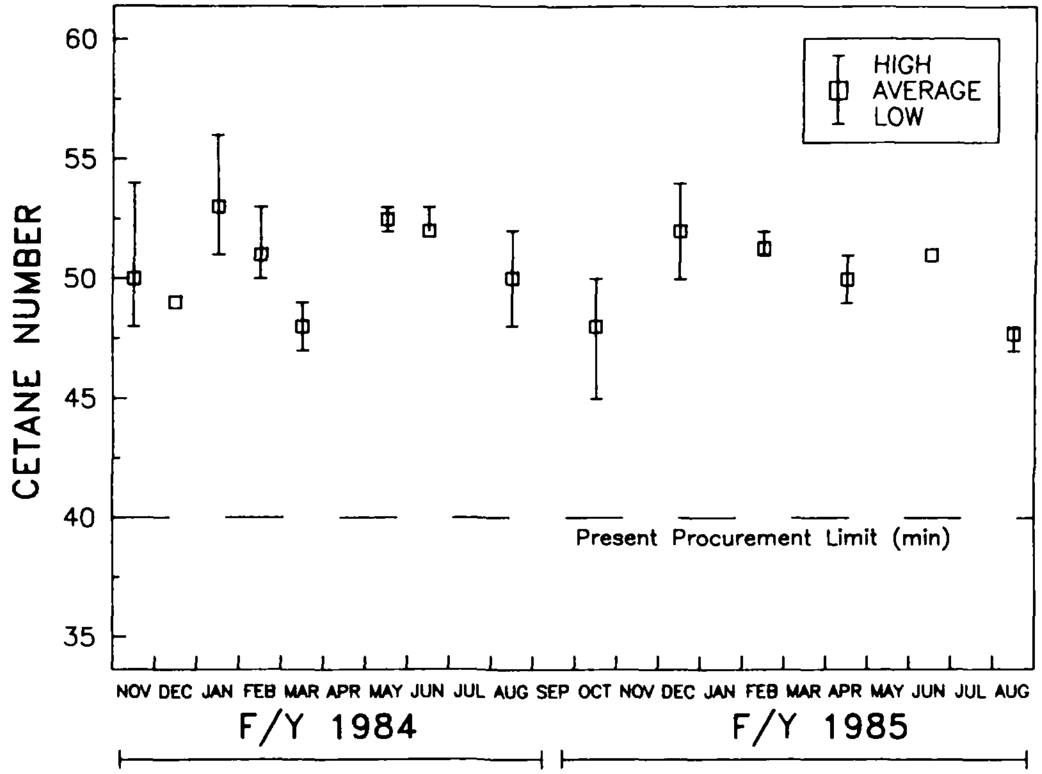


FIGURE 14. HIGH, AVERAGE, AND LOW VALUES FOR CETANE NUMBER, D 613 (DUGWAY PG)

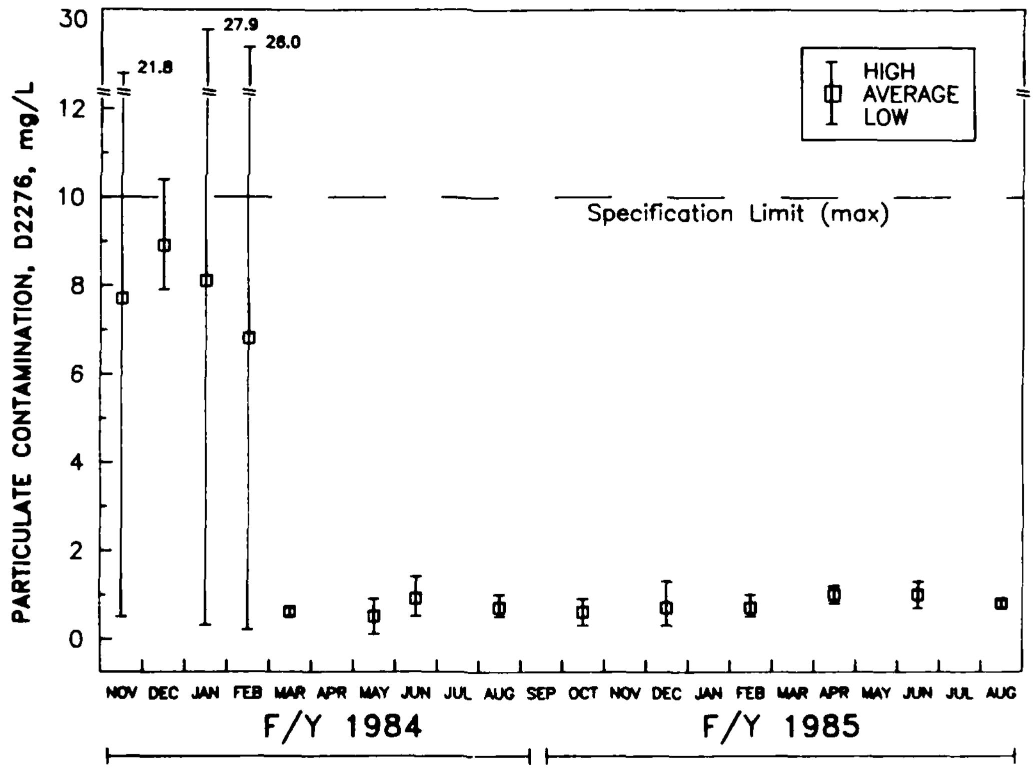


FIGURE 15. HIGH, AVERAGE, AND LOW VALUES FOR PARTICULATE CONTAMINATION, D 2276, mg/L (DUGWAY PG)

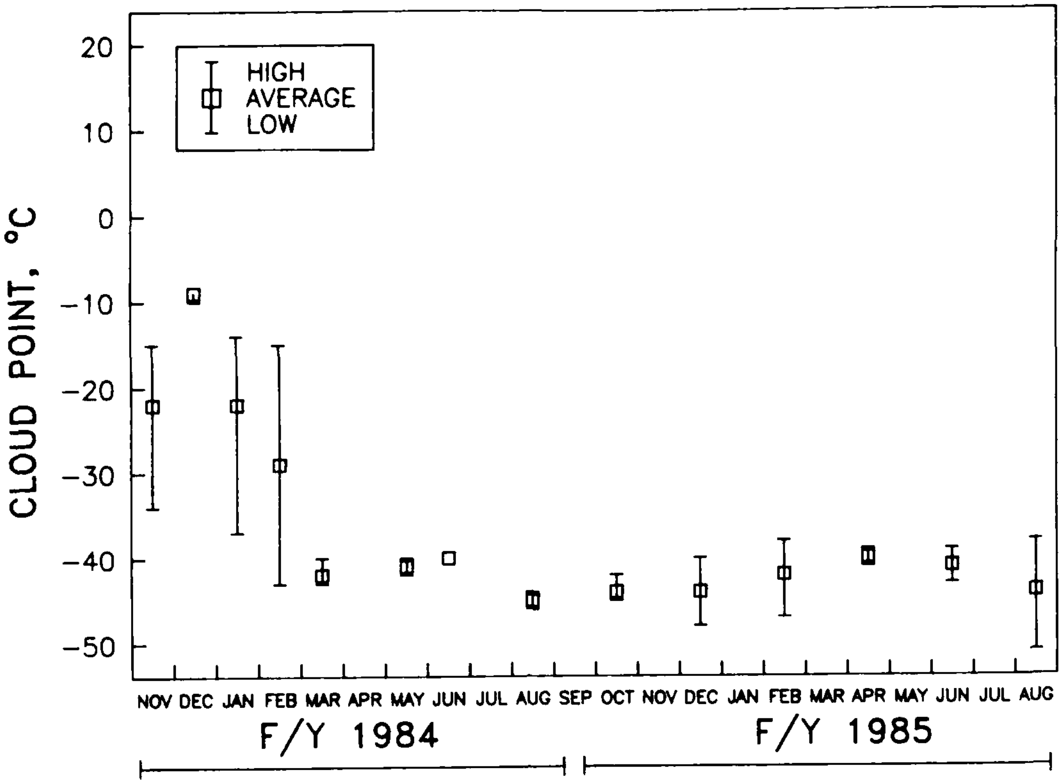


FIGURE 16. HIGH, AVERAGE, AND LOW VALUES FOR CLOUD POINT, D 2500, °C (DUGWAY PG)

Water bottoms have been found in the tanks. However, this condition is common in underground tanks and does not appear to have caused any problems to date.

An unsatisfactorily high Fuel System Icing Inhibitor (FSII) content in one of the airfield's JP-4 bulk storage tanks was discovered during routine testing. A solution was submitted to the airfield manager and, upon implementation of the suggestions, the problem was corrected.

Dugway personnel have been very conscientious in maintaining the fuel storage tanks and in the use of proper procedures for fuel handling.

VIII. OVERVIEW OF MAINTENANCE RECORDS

At Fort Carson, CO, a distinction had to be made between divisional (4th Infantry Division (Mechanized)) and nondivisional units because of different supply and distribution systems. For nondivisional units the usage rate for diesel fuel ranged

between 50,000 and 70,000 gallons per month. Because of the different mission/training cycles pertaining to divisional units, widely fluctuating quantities of fuel were used, which made simple averaging for gallons per month infeasible. Therefore, for divisional units at Fort Carson and for the ground equipment and vehicles at Dugway Proving Ground, a ratio was computed using total miles driven and total gallons of diesel fuel consumed for each reporting period for which such data were received. The ratios of 1.9:1 to 2.9:1 appear to hold true within a certain range regardless of the length of time period used and miles and gallons accumulated during that length of time. However, for FY84 a ratio was not computed for Dugway Proving Ground because the total mileage provided was suspect. The JP-4 fuel usage at Michael Army Airfield at Dugway Proving Ground showed a notable difference between 1984 and 1985. The reason for this difference is believed to have occurred because of the amount of time Michael Army Airfield was shut down for major repairs to the runway and maintenance building apron. The JP-4 fuel usage at Michael Army Airfield reported for FY84 was 185,707 gallons and for FY85 the usage was reported as 128,316 gallons. The Utah Army National Guard Salt Lake City Airport No. 2 reported using 340,404 gallons of JP-4 fuel in 1984 and 295,300 gallons for 1985. It should be noted here that the 1984 report was for a fiscal year and the 1985 report was for a calendar year.

Fuel-wetted parts usage at Fort Carson showed some fluctuations with 14 increases from FY84 to FY85 occurring out of 39 different parts examined. The major increases were in various filter elements and parts kits. Three of the 39 parts showed no change, while the remainder showed modest to significant decreases. A decrease in major component stockage levels (engines, transmissions, and final drives) from 1983 through 1985 taken together with the decrease in fuel-wetted parts revealed a steadily improving maintenance level for the Divisional units.

The sampling activities during the 2-year pretest period together with the interaction between the field monitors and the contact personnel at the different test sites resulted in the most revealing insights thus far obtained about the day-to-day operations of military units in a peacetime environment and will greatly enhance the planning and execution of future field tests.

Finally, it should be noted that, unless the shale fuel actually begins to arrive within a reasonable time, the vehicle mix, operational data, fuel-wetted parts stockage levels, and major component stockage levels will change so that the data obtained thus far will no longer be a valid baseline for the selected test sites.

IX. BENEFITS DERIVED FROM THE MONITORING PROGRAM

The benefits derived from the monitoring program to date include:

1) Development of a diesel and JP-4 fuel sampling apparatus which is effective, efficient, and safe.

   - Relatively inexpensive
   - Allowed large number of samples to be taken in a much shorter period than would be required if other means were used
   - Assures clean fuel samples
   - Prevents spillovers and over-filling of sample containers

2) Resolved a fuel stability test problem Fort Carson personnel had with diesel fuel deliveries. The solution to the stated problem of no fuel stability testing at delivery was for Fort Carson procurement personnel to specify in their request for bids that acceptance of the delivery contract would require stability testing. The solution required coordination between BFLRF, the area QAR, and Fort Carson personnel.

3) Discovery of a large excess of FSII in one JP-4 storage tank at Michael Army Airfield, Dugway Proving Ground, UT.

   - The Michael Army Airfield manager was notified of the problem to preclude use of the fuel in Air Force aircraft which normally come in for refueling at Dugway and Army aircraft stationed at Dugway or nearby National Guard or Reserve Units.
   - The correct percentage, by volume, for FSII in JP-4 fuel was given to the Michael Army Airfield manager with a suggestion that the fuel be mixed with JP-4 in the other two tanks resulting in an acceptable level of FSII in all three tanks.

4) Identifying water bottoms in fuel storage tanks at Fort Carson.

- The level of water present in the tanks was reported to maintenance personnel in inches, and suggestions were made for procedures to remove the water.
- At the request of Fort Carson personnel, a siphoning system was developed to remove water from the bottoms of the tanks.

5) Assisted Fort Carson personnel in the resolution of a problem with plugged primary fuel filters in several tracked vehicles. The problem was identified as severe microbiological contamination. Appropriate remedial action was provided.

6) Provided a prototype Field Fuel Quality Monitor and instructional classes for use by Fort Carson personnel.

7) Through analysis of routine samples, discovered the presence of a low flash point contaminant (gasoline) in several of the diesel storage tanks at Fort Carson. Appropriate personnel were advised.

8) The routine periodic sampling and analysis of fuels have provided an excellent baseline assessment of the condition and quality of the storage tanks and fuel supplies at each site. These analyses have also identified those fuel supplies which required special attention because of their condition.

9) Closer coordination between the U.S. Army and the U.S. Air Force:

- Establishing procedures through MRSA for obtaining oil analyses data for Fort Carson, 3rd ACR, Fort Bliss, TX and the 2/6th Cavalry, Fort Knox, KY on magnetic computer tapes from Kelly Air Force Base, San Antonio, TX.
- Providing and correlating test data for Air Force engines with comparable Army aircraft engines to support a decision by AVSCOM to allow Army military aircraft to participate in the shale fuel program.

- o Joint participation with the U.S. Air Force in a round-robin Ball-On-Cylinder Lubricity Evaluation (BOCLE).
- o Cooperation with the Air Force by providing sampling procedures and sampling equipment to the Utah Army National Guard and Michael Army Airfield at Dugway Proving Ground, UT to allow close monitoring of the amount of corrosion inhibitor lubricity additive in JP-4 fuels delivered to those two activities.

10) Made available valuable vehicle and equipment operational data and component usage to the agencies conducting the test which will permit better field testing procedures for future user acceptance programs to be developed.

X. CURRENT STATUS

Because of Union Oil Company's continued technical problems caused by the system for conveying heated shale rock, no shale-derived fuel has yet been produced, upgraded, and refined for the Field Validation Program for Shale-Derived Fuels.

In view of these circumstances, the efforts and money committed to the validation test have been reduced to a minimum. No further field fuel sampling trips will be made by Belvoir Fuels and Lubricants Research Facility (SwRI) until a firm date has been established for delivery of shale-derived fuels to the test sites.

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